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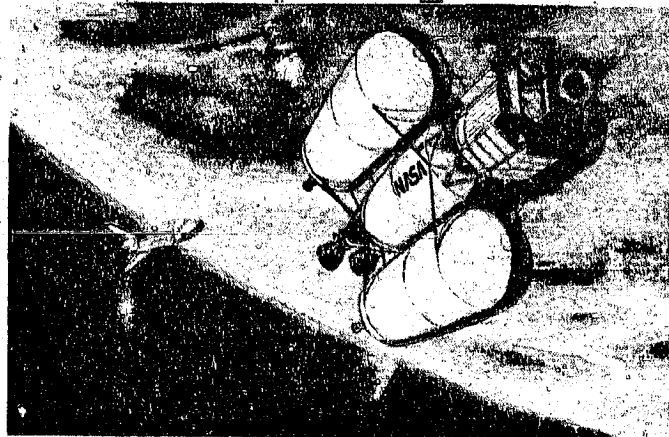
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MANNED ORBITAL TRANSFER VEHICLE (MOTV)

volume 6
five year program plan



GRUMMAN AEROSPACE CORPORATION

**MANNED ORBITAL
TRANSFER VEHICLE
(MOTV)**

volume 6
five year program plan

prepared for
National Aeronautics and Space Administration
Johnson Space Center
Houston, Texas

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CONTENTS

<u>Section</u>	<u>Page</u>
1 INTRODUCTION	1
2 PROGRAM STRATEGY	1
3 PROGRAM GOALS/OBJECTIVES	1
4 PROGRAM ELEMENTS	2
5 PROGRAM CONSTRAINTS	2
6 PLANNING ASSUMPTIONS	5
7 SCHEDULE & MILESTONES	6
8 PROGRAM CONTENT	8
8.1 System Integration & Crew Module Definition	8
8.1.1 System Integration Activity in Phase A/B	8
8.1.2 Manned Crew Module Designs for Phase A/B Study	9
8.1.3 Turnaround Operations for Phase A/B Study	10
8.1.4 Phase A/B Study Plan/Schedule	11
8.1.5 System/Crew Module Development & Acquisition	13
8.1.6 System/Crew Module Schedule & Cost	15
8.2 Propulsion Module	18
8.2.1 Propulsion Module Designs for Phase A/B Study	18
8.2.2 Phase A/B Study Plan/Schedule	18
8.2.3 Propulsion Module Development & Acquisition	18
8.2.4 Propulsion Module Schedule & Cost	19
8.3 OTV Engine	19
8.3.1 Phase B Study Plan/Schedule	19
8.3.2 OTV Engine Development & Acquisition	20
8.3.3 OTV Engine Schedule & Cost	20

CONTENTS (contd)

<u>Section.</u>	<u>Page</u>
8.4 Supporting Research & Technology (SR&T)	20
8.5 Manned Mission Development	21
9 MOTV INTEGRATED SCHEDULE & COST	28

ILLUSTRATIONS

<u>Fig.</u>		<u>Page</u>
4-1	S1 Mission: Groundrules & Assumptions.	3
4-2	MOTV GEO Transfer Configuration for Mission S1.	3
4-3	3-Man Crew Capsule: S1 Mission	4
7-1	MOTV Phased Development Program Plan, Summary Schedule	7
8-1	System Integration & Crew Module Definition Phase A/B Study Plan	12
8-2	Phase A/B Study Milestone Schedule	14
8-3	MOTV WBS	15
8-4	MOTV Phased Development Program Plan Master Schedule	16
8-5	Crew Capsule Development/Production Cost - Mission S1 (Constant 1979 \$ M)	17
8-6	Supporting Research & Technology, Solar Flare Prediction	22
8-7	Supporting Research & Technology, CM Flight Station Simulation	23
8-8	Supporting Research & Technology, On-Orbit Assembly Simulation	24
8-9	Supporting Research & Technology, GEO EVA Suit Development	24
8-10	Supporting Research & Technology, Main Engine Life & Reliability	25
8-11	Supporting Research & Technology, Propulsion Module Reliability	25
8-12	Supporting Research & Technology, SOC Turnaround Simulation	26
8-13	Manned Mission Development, STS Flight Requirements	26
9-1	MOTV Development/Production Cost Summary - Mission S1 (25% Weight Contingency Reflected - Constant 1979 \$ M)	29
9-2	Annual MOTV Program Funding Requirements.	29
9-3	Annual MOTV Studies & SR&T Funding Requirements	30

FOREWORD

This final report documents the results of a study performed under NASA Contract NAS 9-15779. The study was conducted under the technical direction of the Contracting Officer's Representative (COR), Herbert G. Patterson, Systems Design, Johnson Space Center. Mr. Lester K. Fero, NASA Headquarters, Office of Space Transportation Systems, Advanced Concepts, was the cognizant representative of that agency.

The Grumman Aerospace Corporation's study manager was Charles J. Goodwin. The major contributors and principal investigators were Ron E. Boyland, Stanley W. Sherman and Henry W. Morfin.

This final report consists of the following volumes:

- Executive Summary - Volume 1
- Mission Handbook - Volume 2
- Program Requirements Document - Volume 3
- Supporting Analysis - Volume 4
- Turnaround Analysis - Volume 5
- Five Year Program Plan - Volume 6

1 - INTRODUCTION

This document presents the Five Year Program Plan for the Manned Orbit Transfer Vehicle (MOTV). Included herein are the planning, schedules, cost estimates and supporting data (objectives, constraints, assumptions, etc.) associated with the development of the MOTV.

The plan, in addition to the above material, identifies the Supporting Research and Technology required to resolve issues critical to MOTV development.

2 - PROGRAM STRATEGY

The strategy of the MOTV Program, consistent with the basic NASA strategy to capitalize and build-on the Shuttle capabilities in order to meet the mission requirements which fulfill national space objectives, is to extend NASA's ability to provide satellite services to remote and high-energy orbits. The planned strategy is a two-step approach, initially providing an unmanned orbit transfer vehicle (OTV) capability and subsequently by modular growth providing a manned orbit transfer vehicle (MOTV) capability.

3 - PROGRAM GOALS/OBJECTIVES

The goals of the MOTV Program are (a) to provide the capability to deploy large payloads in geosynchronous orbits beyond the capability of the IUS and (b) to provide manned capability in geosynchronous orbits to service deployed payloads and/or perform advanced missions. Payload deployment to GEO without man is an interim goal planned for mid '87 operational capability. The advanced missions capability including manned satellite inspection, servicing and repair and fabrication, assembly and checkout of advanced systems such as space solar power development articles has an IOC prior to the end of '88 as a goal.

The objectives consistent with the goals described in the above paragraph are:

- (a) to complete Phase A studies to explore alternative concepts for the OTV Engine and Propulsion Module.
- (b) to update the results of the Manned Geosynchronous Mission Requirements and Systems Analysis Study (MGMRSAS) to incorporate the results of the above referenced Phase A studies.
- (c) to define OTV system requirements for Engine, Propulsion Module and Crew Module concept definition.

- (d) to perform Phase A/B and B studies for System, Crew Module, Propulsion Module and Engine concept definition
- (e) to design, develop, fabricate, assemble and checkout Propulsion Module/Engine and Crew Module hardware to provide both unmanned and manned OTV operational capability.
- (f) to identify all critical technology issues relevant to the achievement of a manned OTV operational capability.

4 - PROGRAM ELEMENTS

As a result of the MGMRSAS, a MOTV program has been formulated to satisfy the baseline S1 Mission. The ground rules and assumptions associated with the S1 Mission are given in Fig. 4-1. Similarly, the MOTV configuration and Crew Module or Capsule which have been conceptually developed to meet the S1 Mission requirements are shown in Fig. 4-2 and 4-3, respectively.

The program elements in the context of the MOTV Program are best described in terms of four major activities, (1) System Integration and Crew Module Definition, (2) Propulsion Module Definition, (3) Engine Definition and (4) Supporting Research and Technology (SR&T).

The System Integration and Crew Module Definition activity includes the translation of planned missions into system requirements, the definition/production of the Crew Module, the integration of the system and the development of system operational concepts.

The Propulsion Module Definition consists of translating unmanned and manned system requirements into detailed module requirements, defining/producing the Propulsion Module to satisfy these requirements, and establishing the Propulsion Module interface and operational definition.

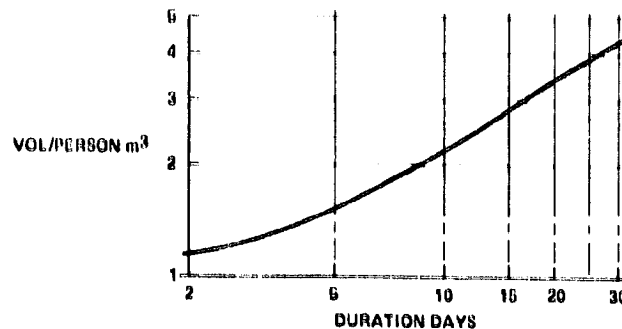
The Engine Definition activity encompasses the same tasks described above for the Propulsion Module. The SR&T activity includes all the technology issues critical to the timely development of the MOTV capability.

5 - PROGRAM CONSTRAINTS

The MOTV Program Plan is constrained by the following milestone dates and ground rules:

- (a) The MGMRSAS Phase A Study is completed in 1979.

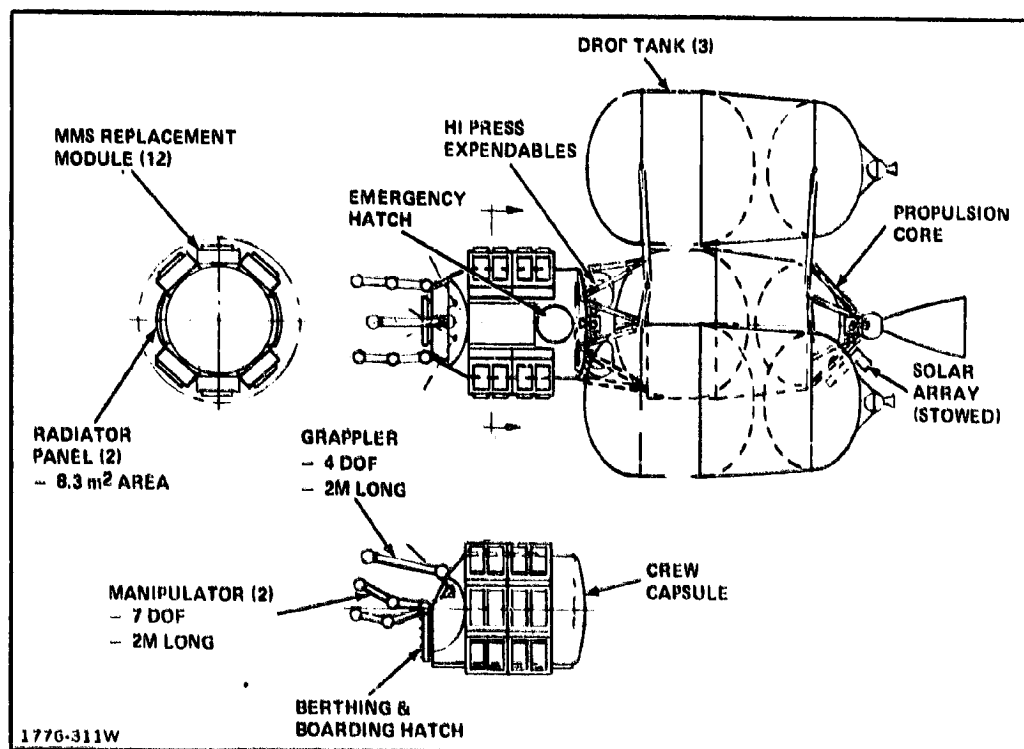
- SERVICE 4 COMM SATELLITES, 90° APART IN GEO, REPLACE 3 MMS MODULES ON EACH
- 1-1/2 STAGE APOTV: DROP TANKS DEORBITED
- ALL MOTV COMPONENTS STS COMPATIBLE & ASSEMBLED AT 200 x 200 N MI, 28.6° ORBIT
- MOTV CREW CAPSULE SIZED TO ACCOMMODATE 3 PEOPLE FOR 18 DAYS
- FREE VOL/PERSON TO BE



- MIXED GENDER CREW: 95 PERCENTILE MALE TO 5 PERCENTILE FEMALE
- IVA TO BE PRIMARY MISSION OPS METHOD: EVA WHERE NECESSARY & EMERGENCY
- NO DEDICATED AIRLOCK
- WEIGHT CONTINGENCIES
 - 25% FOR CREW CAPSULE
 - 15% FOR PROPULSION
- USE ASTRONAUT RADIATION LEVEL

1776-310W

Fig. 4-1 S1 Mission: Groundrules & Assumptions



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Fig. 4-2 MOTV GEO Transfer Configuration for Mission S1

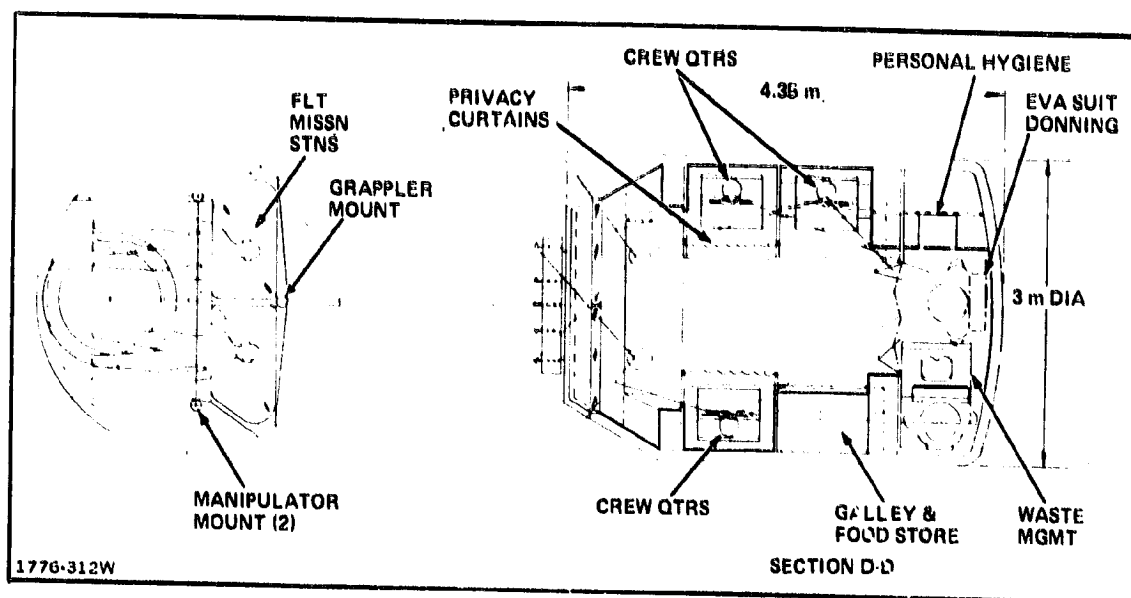


Fig. 4-3 3-Man Crew Capsule: S1 Mission

- (b) Phase A studies for the Propulsion Module and Engine are completed in 1980.
- (c) The Propulsion Module and Engine are initially developed with a man-rated capability to provide for dual-mode operation, i.e., manned or unmanned.
- (d) The Authorization-to-Proceed (ATP) for the MOTV capability with the Crew Module occurs in the latter part of 1983 or early in 1984.
- (e) The Initial Operational Capability (IOC) dates for the unmanned and manned OTV are 1987 and 1988, respectively.
- (f) The program plan is based on ground MOTV turnaround although Space Operations Center (SOC) OTV turnaround will be studied as an option.

6 - PLANNING ASSUMPTIONS

In developing the five year program plan for the MOTV, a number of assumptions were made as described below:

- (a) The program plan covers the period 1980 through 1984. Top level planning has been formatted to IOC to insure timely development of all program elements.
- (b) The Phase A studies for the System/Crew Module, Propulsion Module and Engine are followed by Phase A/B Studies for refinement of the requirements and concepts.
- (c) The baseline MOTV to be developed includes:
 - Crew Module
 - APOTV Propulsion Module
 - RLIO Der. IIb Type Engine
 - Drop Tanks
 - Ground/Flight Support Equipment
- (d) The program costs include and are broken out in the following categories:
 - Phase A/B Studies
 - Phase B Studies
 - Phase C/D hardware design/development/production
 - Supporting Research and Technology (SR&T)

- (e) Space turnaround option is based on the SOC facility defined by the JSC SOC Preliminary Study Report dated May 18, 1979.
- (f) The costs included for the MOTV phase C/D program are based on the following ground rules/assumptions:
- Cost data in 1979 constant dollars
 - Crew salaries and space suits (except for SR&T) are excluded.
 - Three Shuttle flights are required for MOTV development.
 - 1 equivalent unit of each subsystem required for ground test
 - Support equipment cost includes one set for development
 - Non-replicated weights used for development cost computation.
 - Drop tank cost per mission based on the average production unit cost of 60 units at 85% learning.
 - Crew Module and Propulsion Module costs are based on estimated weights including 25% and 15% contingency, respectively.
 - Spares included only for production.

7 - SCHEDULE & MILESTONES

The top level schedule for the MOTV program is shown in Fig. 7-1, and is amplified by the Master Schedule presented in Fig. 8-4, section 8.16. As noted above, it includes the five year development plan, '80 - '85, as well as the phasing to achieve a manned IOC in 1988. Major milestones to the manned IOC are also identified.

The major milestones include the NASA review/budget approval dates for a phased MOTV development; Module mock-ups and required dates for MOTV development; and IOC dates for the unmanned and manned OTVs.

The schedule in Fig. 7-1 shows the phasing of four major activities - contracted studies, future studies, phase C/D and SR&T. The contracted studies include the MGMRSAS, Propulsion Module and Engine phase A studies. Phase A/B type studies have also been awarded for point designs of the expander type engine. The future studies include phase A/B type studies for the System/Crew Module and Propulsion Module to refine mission/design/operational requirements definition. The results of the phase A/B studies provide the basis for NASA decisions to proceed with phase B studies for the System/Crew Module, Propulsion Module and Engine.

Based on the results of the three phase B studies (complete or partial), a NASA decision is made to proceed with a 1982 Phase C/D go-ahead for the unmanned OTV.

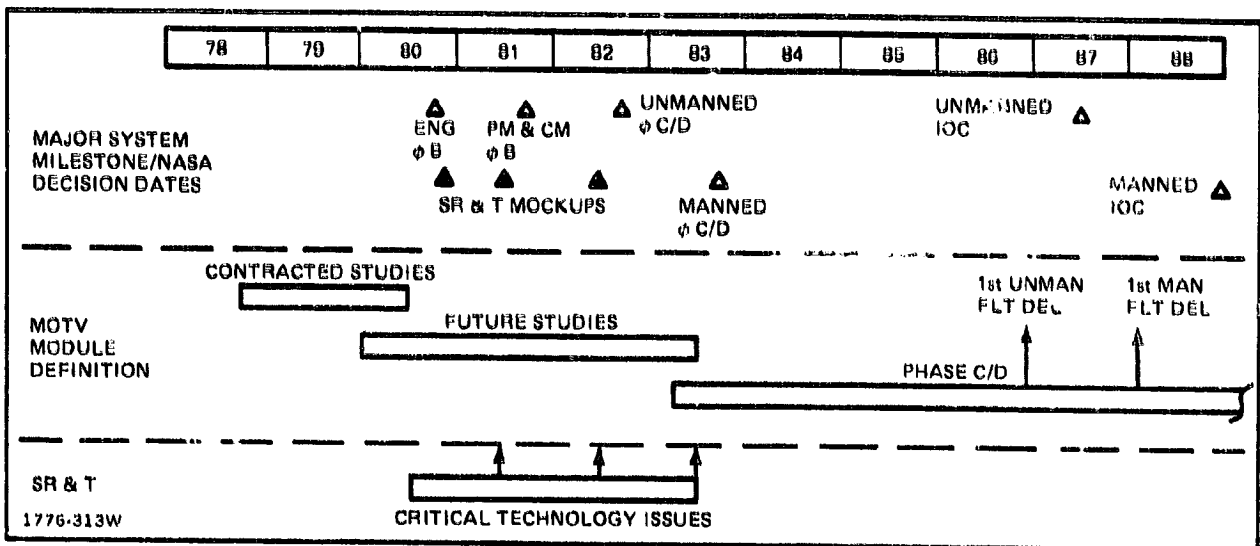


Fig. 7-1 MOTV Phased Development Program Plan, Summary Schedule

Although this approval is for an unmanned OTV, the Engine Phase C/D and the subsequent Propulsion Module Phase C/D have an initial requirement for man-rating. Following the completion of all Phase B studies, a NASA decision is made in 1983 to proceed with the manned OTV Phase C/D. The culmination of these activities is the 1st unmanned OTV flight in 1987 and the 1st manned OTV flight in 1988.

Engine, Propulsion Module and Crew Module are appropriately phased for delivery, integration and flight. The mock-ups are phased to the SR&T program which in itself is phased to the program milestones as discussed in detail in subsection 8.4.

8 - PROGRAM CONTENT

The content of the MOTV development program is presented and discussed in five areas as outlined below:

- (a) System Integration and Crew Module Definition
- (b) Propulsion Module
- (c) OTV Engine
- (d) SR&T
- (e) Manned Mission Development

For the first three areas, Phase A/B or B study activities are described and discussed, hardware development and acquisition planning are presented and schedules and costs are detailed. The SR&T area addresses the technology issues critical to the MOTV. For each issue, the reason for the criticality is discussed, schedule and phasing requirements are presented and cost requirements summarized. The Manned Mission Development identifies the planned orbital activities to achieve a manned GEO capability.

8.1 SYSTEM INTEGRATION & CREW MODULE DEFINITION

8.1.1 System Integration Activity in Phase A/B

The basic objectives of the Phase A/B study in system integration are to incorporate the results of the Propulsion Module and Engine Phase A studies and to refine mission/system requirements and interfaces/program planning. Alternate missions to the baseline design reference mission (DRM) will be considered and various scenarios of manned activity, particularly as they differ from the DRM, will be defined. The alternate missions will encompass requirements for short duration (2 day) and long duration (30 day) missions with crew sizes from 2 to 8 including passengers. The

alternate missions will be prepared to the same depth as the baseline DRM. Detailed manned system requirements will be derived from these alternate missions. The MOTV Requirements Document and Mission Handbook will be updated to reflect the alternate missions.

Requirements for man rating will also be assembled for the MOTV system, including rationale and trades to justify their inclusion. Requirements for subsystem reliability and redundancy will be assessed to assure crew safety. A preliminary MOTV top specification will be prepared and include these "man rating" requirements.

The systems integration activity will also refine the MOTV subsystem definition and identify the interfaces between the Crew Module and Propulsion Module subsystems. Finally, the system integration activity will update cost and schedule data on the MOTV. The update will reflect the results of alternate mission definitions and crew module/subsystem modifications. All costs will be presented showing uncertainties about the mean.

The five year MOTV Program Plan will be updated to reflect new data from alternate missions and/or modified definitions. Long pole or critical development items will be identified. Critical technology issues and precursor test programs which are needed to support the MOTV program or major decision milestones will also be updated. The program plan update will include Phase B and C/D plans and schedules, as well as a preliminary test plan which identifies major test articles needed for MOTV development.

8.1.2 Manned Crew Module Designs for Phase A/B Study

The Crew Module conceptual design developed to satisfy DRM will be reviewed and reassessed considering the alternate missions and the updated MOTV Requirements Document defined by this Phase A/B study. To this end, performance analyses will be conducted to the level necessary for crew capsule definition, internal layout preparation, and general purpose/mission dedicated equipment location. Necessary trade studies will be performed to minimize development and production costs of the baseline MOTV and the "mini mods" required to accommodate alternate mission scenarios.

The crew module activity will also develop modifications to the baseline subsystems to accommodate the varying crews and durations required by the alternate mission scenarios. These modifications will be minimum changes to the baseline subsystem and will not result in new subsystem designs optimized for each mission. The impact

of these "mini Mods" will be clearly defined in terms of performance, logistics, operations, cost and Propulsion Module Interface. Where "mini mods" are impractical or impossible, a dedicated subsystem will be identified and design, performance and cost characteristics determined. The subsystem definition will also include man rating requirements (e.g., redundancy, back up system, contingency) and the rationale for their use.

The Crew Module Activity will consider the design impact of operational requirements for both ground and space MOTV turnaround. These operational requirements will be updated versions as developed by the activity described in Subsection 8.1.3.

8.1.3 Turnaround Operations for Phase A/B Study

Utilizing the updated mission, system requirements and Crew Module definitions produced by the Phase A/B study, the requirements for flight and ground operations will be defined in depth. The operations definition will include turnaround and support requirements and consider both ground based and space based turnaround, with the latter using the Space Operations Center (SOC) facility. The requirements for each mode of turnaround will be fully identified.

Detailed timelines, manpower and ground based/space based facilities will be identified for the MOTV turnaround. No new facility requirements have been identified to date for ground MOTV turnaround. Space based equipment for SOC turnaround will be defined as deltas to the basic SOC. Interface requirements between the Crew Module, Propulsion Module, STS, SOC and ground facilities will be defined to assure compatibility during servicing, safing and other turnaround operations. Requirements for abort, component changeout on the launch pad, DOD peculiar requirements, orbital flight instrumentation (OFI), launch processing system (LPS) interfaces and software will also be identified. GSE requirements including interface, configuration and performance will be defined. Preliminary MOTV spares provisioning will also be developed.

Flight operations requirements will be established and a mission plan developed to include orbital timelines, mission related hazard analyses and contingency plans.

Maintenance and mission sensitive trades will be conducted to select low cost approaches to flight and ground operations. These trades will include but not be limited to OFI versus LPS checkout and horizontal versus vertical MOTV turnaround processing.

8.1.4 Phase A/B Study Plan/Schedule

The basic objective of the System Integration and Crew Module Definition Phase A/B Study is to utilize the OTV related Phase A studies, which either have been or will be completed in the near future, to develop alternate missions to the baseline design reference mission and to assess the impact of these alternate missions on requirements, designs, interfaces, schedules and cost.

The task flow and milestone schedule for this Phase A/B study are shown in Fig. 8-1 and 8-2, respectively. As shown in Fig. 8-1, the study activity is logically grouped into five tasks. The inputs for these tasks are the overall study inputs and the outputs of specific tasks of this study, also shown in Fig. 8-1.

Task 1, Mission Definition and Manned System Requirements, evaluates alternate missions to the design reference mission with various scenarios of manned activity. Alternate missions are selected and utilized to update the manned system requirements and mission handbook. The manned system requirements, including man-rating features such as subsystem reliability and redundancy for crew safety, are documented in a preliminary MOTV top-level specification.

The outputs of Task 1, in conjunction with the study inputs, are used to perform Task 2, Crew Module Definition. Previous Crew Module designs are reviewed and modified to meet updated system requirements. The basic approach is to meet these varying requirements by minimum modification of the basic Crew Module design. Preliminary design drawings and mission scenario sequences are prepared for the alternate requirements and missions. The efforts of this task are iterated as required by the outputs of Tasks 3 and 4.

Task 3, Subsystem and Interface Definition, defines the subsystems and module interfaces to accommodate alternate mission/system requirements. These definitions are based on the study inputs and the outputs of Tasks 1 and 2.

The outputs of Task 3, as well as Tasks 1 and 2, are utilized to define flight and ground operations. The options considered include space (SOC) and ground turnaround. Consistent with the alternate mission/requirements, operational requirements including facilities, manpower, support equipment, interfaces, servicing, maintenance, software and spares are defined.

Task 5, Programmatic and Cost, uses the outputs of all the other tasks to update cost and schedule data provided as study inputs. The five year program plan is

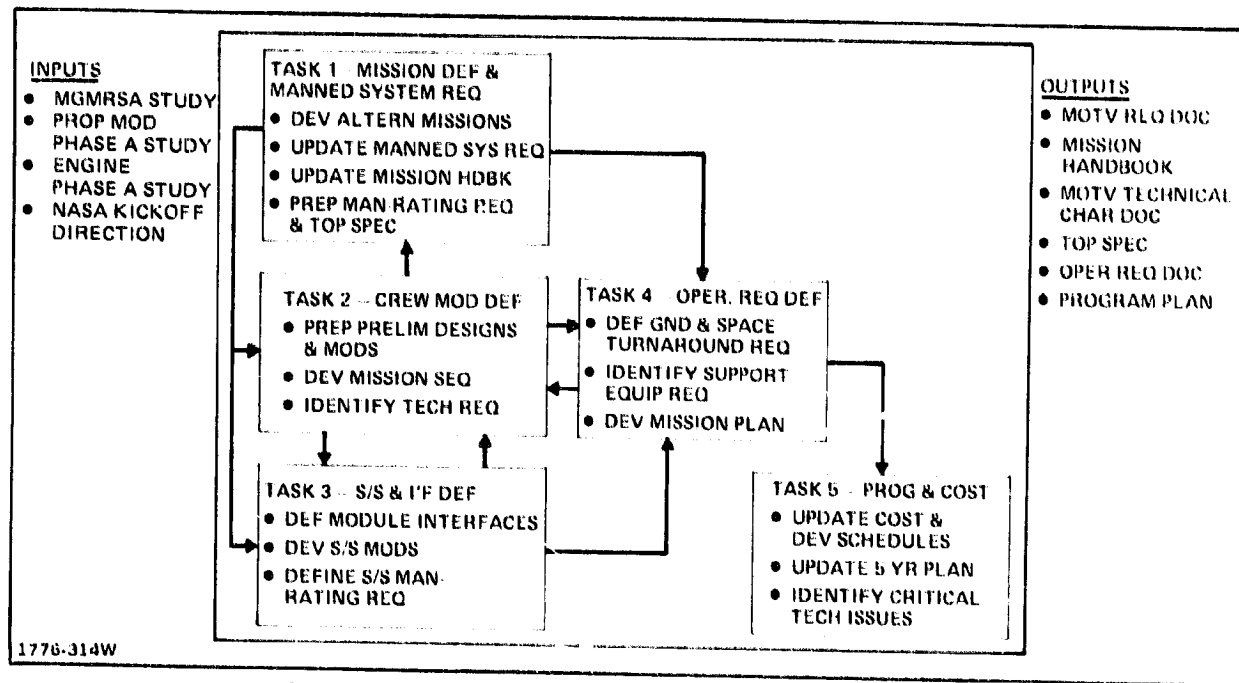


Fig. 8-1 System Integration & Crew Module Definition Phase A/B Study Plan

updated to reflect the latest data including critical development and technology items, schedules, plans and costs.

The results of the Phase A/B study are documented by the five reports noted in Fig. 8-1 as study outputs.

The study milestone schedule, Fig. 8-2 identifies the study milestones, tasks, reviews and documentation output. It is based on the task flow logic of Fig. 8-1. The milestones include quarterly NASA briefings and a final study presentation to NASA. "In-house" reviews are conducted with the Grumman Study Review Board created to support this effort. Progress reports are provided to NASA monthly, except where quarterly reviews are scheduled wherein Performance Review Documents are provided in their place. Draft and final reports are submitted as noted in Fig. 8-2.

The time phasing of the study tasks is also shown in Fig. 8-2. The duration and sequencing of these tasks is commensurate with the required activity and their appropriate interrelationships.

8.1.5 System/Crew Module Development & Acquisition

MOTV development and acquisition are best discussed within the framework of the program Work Breakdown Structure (WBS) shown in Fig. 8-3. The system development and acquisition discussed in this section include all of the hardware items of Fig. 8-3 except the Propulsion Module. The development and acquisition of the Propulsion Module and its Engine are discussed separately in Subsection 8.2.3 and 8.3.2, respectively.

The System/Crew Module development and acquisition are based on the extension of the Phase A contract to perform a Phase A/B Study, a Phase B Study competition with two contractors and the selection of one contractor to design, manufacture and test the Crew Module and integrate the MOTV system. This approach is contingent upon Propulsion Module/Engine study results and the ability of the SR&T program to resolve critical technology issues.

The grapppler, manipulator and standard EVA tools/checkout equipment require development and acquisition but are part of the Crew Module. Other hardware items such as the Ground Support System, Flight Support Equipment and Drop Tank are separate program elements which require design and fabrication and/or procurement. They are separate WBS items not included in the CM or PM but since the development and acquisition are relatively straight forward they are not discussed in detail in this

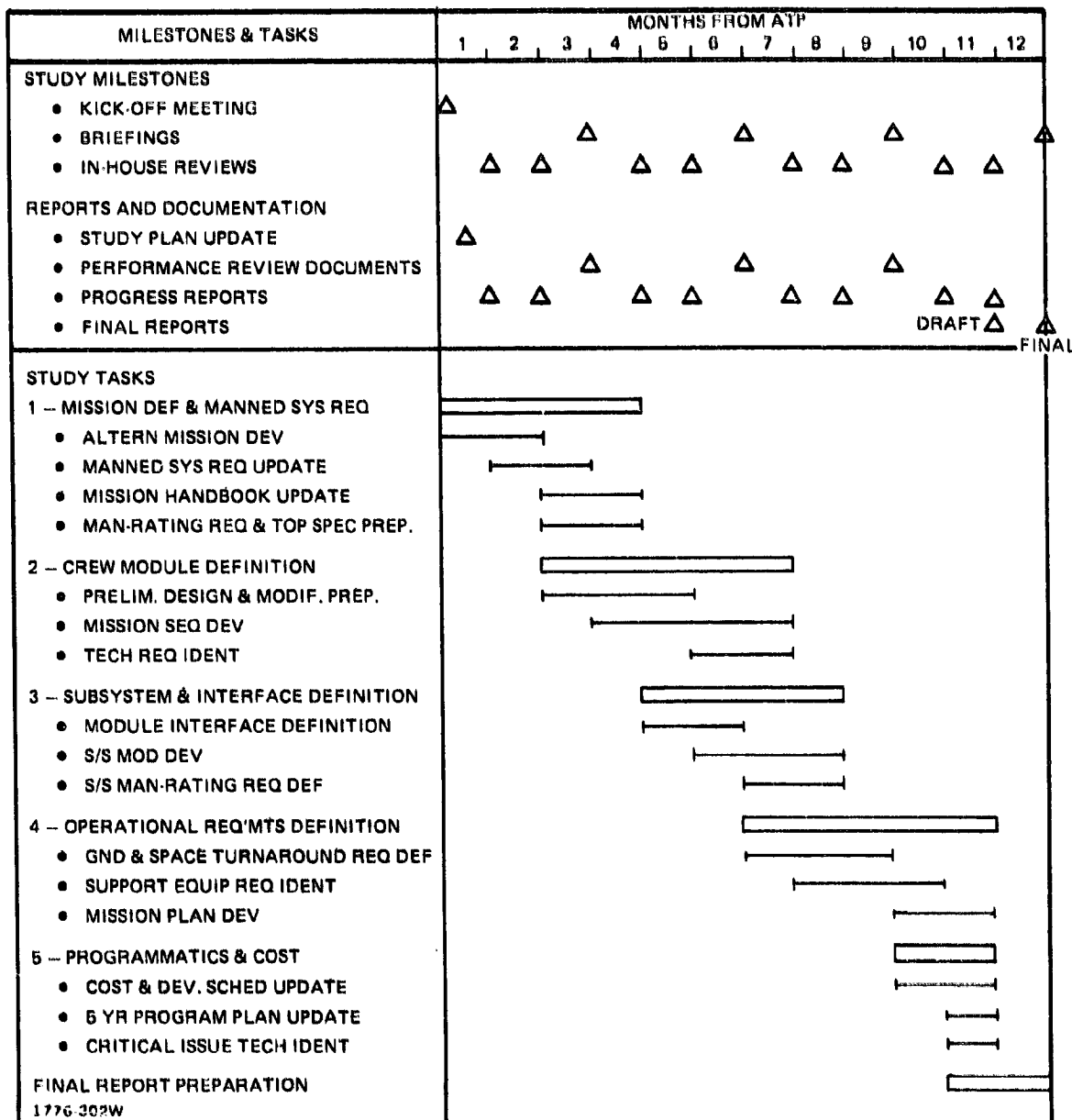


Fig. 8-2 Phase A/B Study Milestone Schedule

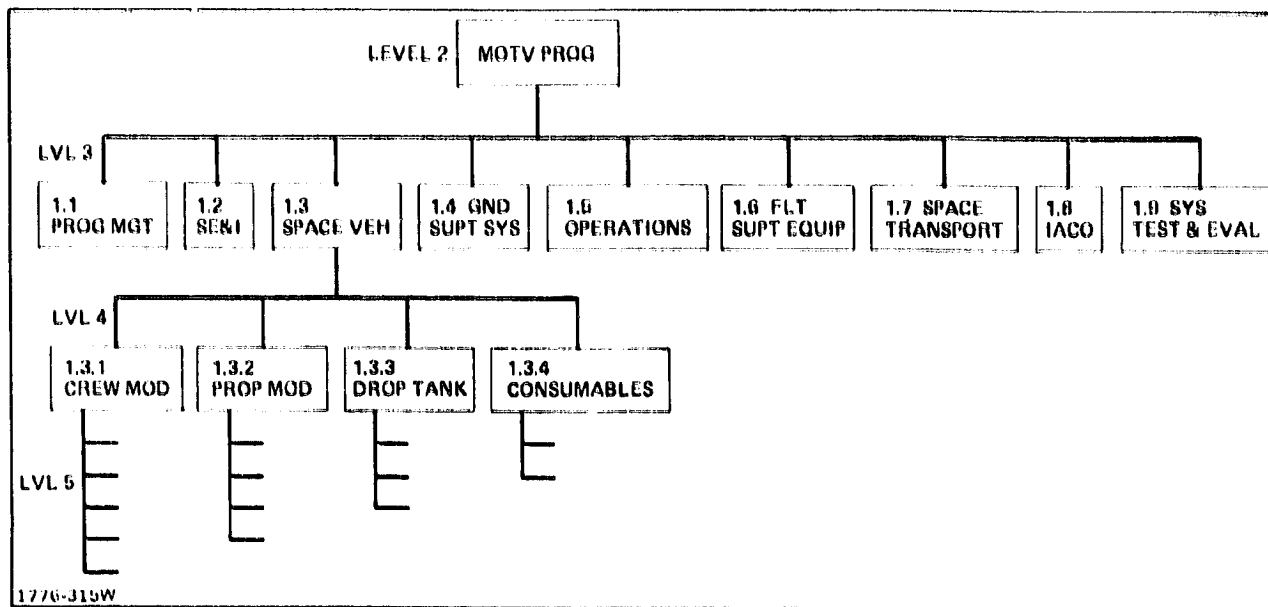


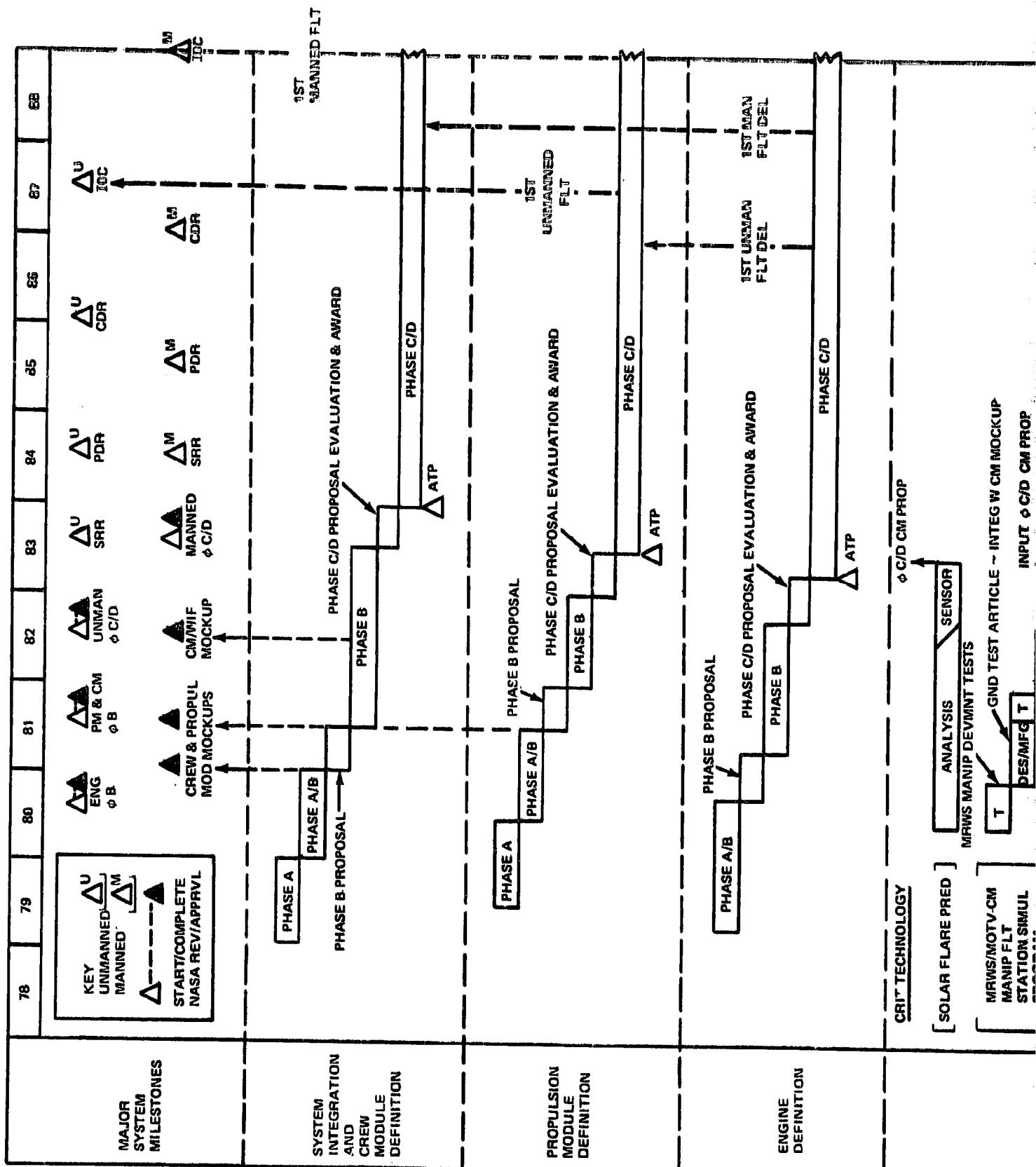
Fig. 8-3 MOTV WBS

five year plan. Subsequent revisions of the plan will consider the development and acquisition of these items.

8.1.6 System/Crew Module Schedule & Cost

The Master Schedule for the MOTV Phased Development Program Plan is given in Fig. 8-4. This schedule, in addition to amplifying the milestones and module activity shown in Fig. 7-1, details the critical issues phased to the MOTV study and hardware activity. The critical issues cover both critical technology items requiring SR&T programs and major cost impact technology issues which must be traded during the MOTV studies. All critical issue activities are scheduled to support the established system milestone dates.

The MOTV program costs for the Crew Capsule exclusive of the study/SR&T costs are tabulated in Fig. 8-5. Figure 8-5 shows the costs broken down by major hardware element or function and by program phase, i.e., DDT&E and Production. The \$502M DDT&E costs includes the subsystems in the CM and excludes those portions of the subsystems in the PM. The \$115M Production cost covers two CMs consistent with program planning.



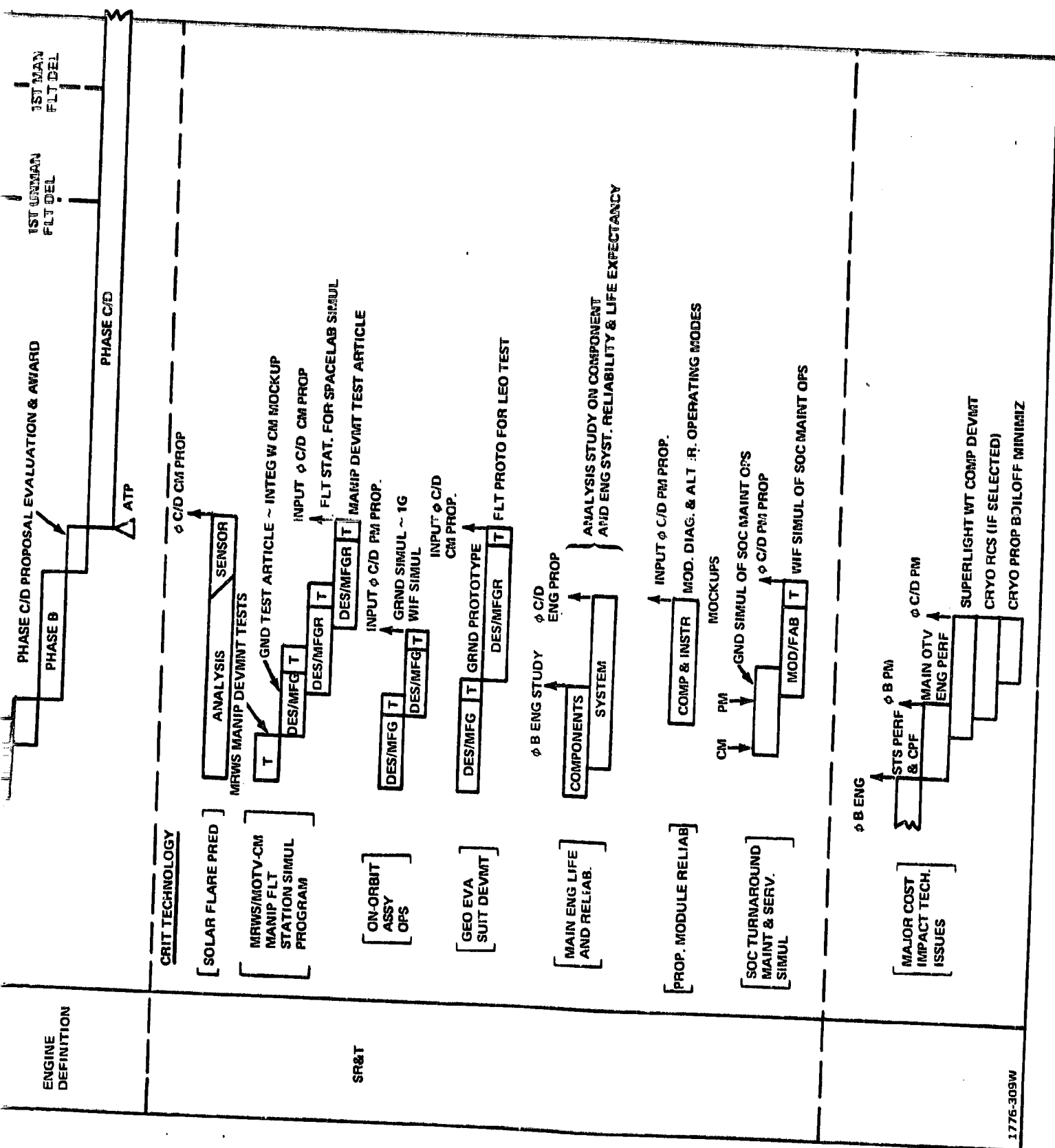


Fig. 8-4 MOTV Phased Development Program Plan Master Schedule

	DDT&E	PROD (2)	TOTAL	
PROJECT MANAGEMENT	40	8	48	
SE & I	33	—	33	
STRUCTURE	101	16	117	
INSULATION	6	1	7	
MECHANISMS	23	13	36	
EPS	2	1	3	} SUBSYSTEMS SPLIT BETWEEN CAPSULE & PROPULSION CORE
AVIONICS	88	13	79	
GN/C	44	7	51	
COMM/DATA HNDLG	6	3	8	
CONT & DISPLAYS	17	3	20	
ECLS	140	30	170	
CREW ACCOM	76	16	92	
O/B SOFTWARE	4	—	4	
SYS TEST & EVAL	11	—	11	
INST-ASSY-CHECKOUT	—	17	17	
1776-324W	602	115	617	

Fig. 8-5 Crew Capsule Development/Production Cost — Mission S1 (Constant 1979 \$ M)

8.2 PROPULSION MODULE

8.2.1 Propulsion Module Designs for Phase A/B Study

Although the PM phase A studies have been formulated with the intent of establishing a recommended PM program, the MOTV program plan proposes an alternative approach. Since the System/Crew Module phase A/B study will be investigating alternate MOTV missions and updating system/subsystem requirements and the Engine phase A/B study will be developing point designs for the expander type engine, the PM phase A/B study as planned will refine the PM configurations/concepts/programs studied in phase A.

Accordingly, the PM designs to be studied in phase A/B include the all propulsive OTV concept and 2 aero-assisted OTV concepts, aero-maneuvering and aerobreaking. The phase A/B will also continue the study of evolutionary options associated with each concept.

8.2.2 Phase A/B Study Plan/Schedule

As discussed above, the basic objective of the proposed phase A/B study is to develop a recommended program for the OTV Propulsion Module. The prime inputs for the phase A/B study are the results of the PM phase A study, the outputs of the System/Crew Module phase A and A/B studies, and the output of the Engine phase A/B studies. The outputs of the phase A/B PM study are a recommended PM program together with related development plan, schedule and cost estimates.

The PM phase A/B study schedule is planned as a 12 month activity. It is proposed as a follow-on extension of the current phase A study contracts with a phased sequence of updating PM requirements, refining concepts and approaches, updating engine/subsystem requirements and refining the definition of selected concepts and development approaches. Each sequence lasts for approximately 3 months with some overlap for interaction between the activities.

8.2.3 Propulsion Module Development & Acquisition

As noted above, the PM activity continues with a follow-on extension for the 2 phase A contractors to perform the phase A/B studies. Subsequent to completion of the phase A/B studies, NASA is expected to select a preferred PM concept/program approach. Based on this selection, a phase B RFP will be released and ultimately 2 contractors will be chosen to perform detailed concept definitions for the selected PM

and to prepare phase C/D proposals. One contractor will be selected to design, fabricate, assemble and acceptance test the Propulsion Module for the unmanned and manned OTV's.

8.2.4 Propulsion Module Schedule & Cost

The schedule for the PM development and acquisition is included in the Master Schedule of Fig. 8-4. Six month periods are planned between phases to allow for RFP finalization/release, proposal preparation and/or proposal evaluation and contract award. Major milestone dates include a PM phase B approval in Oct. '81, an unmanned OTV program approval in Oct. '82, and the first flight PM delivery in mid-'87.

The PM program costs include 1 million dollars for 2 phase A/B contracts, 2 million dollars for 2 phase B contracts and an estimated 460 million dollars for phase C/D including \$391 Million for DDT&E and \$69 Million for Production of 2 flight PM's. The funding requirements for the PM are included in the funding schedules presented in Section 9.

8.3 OTV ENGINE

8.3.1 Phase B Study Plan/Schedule

The basic objective of the OTV Engine Phase B Study is the fabrication, assembly and test of a demonstration engine. This approach is consistent with the current contracts in existence for the OTV Engine. In the Phase A contracts which are scheduled for completion in April '80, the basic objective is to optimize the expander type engine. In the phase A/B study contracts recently awarded and scheduled for completion in Oct '80, three contractors are developing a point design for the expander cycle engine.

The prime inputs for the phase B study are the expander engine point designs produced by the phase A/B studies, available data on the staged combustion engine cycle and the engine requirements produced by the System/Propulsion Module phase A/B studies. The outputs of the phase B engine study are the proposed demonstration engine and its test results, which are expected to verify the feasibility of designing and producing flight engines which meet MOTV requirements, and a proposal for phase C/D.

The schedule for the phase B study is planned as an 18 month activity. The first 3 months are devoted to procurement and manufacture/test planning; the next 12 months to fabrication; assembly and checkout; and the last 3 months to test,

evaluation of results and preparation of a phase C/D proposal. This schedule will require the purchase of long-lead items in the latter part of phase A/B.

8.3.2 OTV Engine Development & Acquisition

The OTV engine development and acquisition in its currently contracted steps are discussed in subsection 8.3.1. In the subsequent activity, a competitive phase B is planned with 2 contract winners. At the conclusion of the phase B completion, NASA is expected to choose the preferred engine cycle and the winning contractor. Assuming an unmanned OTV program go-ahead, the selected phase C/D contractor proceeds to design, fabricate, assemble and acceptance test engines for the unmanned and manned OTV's.

8.3.3 OTV Engine Schedule & Cost

The schedule for the OTV Engine development and acquisition is included in the Master Schedule of Fig. 8-4. Six month periods are planned between phases to allow for RFP finalization/release, proposal preparation, and/or proposal evaluation and contract award. Major milestone dates are an Engine Phase B approval in Oct '80, an unmanned OTV program approval in Oct '82, and the first flight engine delivery at the end of '86.

The Engine program costs include 2 million dollars for the 2 phase B contracts and 84 million dollars for the phase C/D including 2 sets of flight engines. The funding requirements for the OTV Engine are included in the funding schedules presented in Section 9.

8.4 SUPPORTING RESEARCH & TECHNOLOGY (SR&T)

As part of the MGRSA study, a number of critical issues have been identified which must be resolved for an orderly and timely completion of the MOTV program within reasonable cost. These critical issues are categorized into two groups, (a) technical issues which if not solved will preclude MOTV flying and (b) cost issues which have a major impact on program costs. There is a third category of critical issues which relates to technology improvements that are not incorporated into the initial MOTV but are desirable for growth versions. This third category of critical issues will be developed during the follow-on phase A/B study based on the alternate missions formulated in the phase A/B study and the outputs of the Propulsion Module and Engine phase A studies.

The critical technology issues are shown in Fig. 8-4 in order of criticality. Each of these critical issues require an SR&T commitment to support the MOTV program. The reason for the SR&T requirement, the approach for resolution, schedule and cost for each critical issue are given in Fig. 8-6 through 8-12.

The major cost impact critical issues and their planned schedule for resolution are also shown in Fig. 8-4. These issues and their impact on the MOTV will be resolved by analyses and trades performed as part of the phase A/B and B studies. In all cases, these issues have major cost impact and comprehensive analyses/trades are vital to the development of the MOTV program.

8.5 MANNED MISSION DEVELOPMENT

The manned mission development addresses the MOTV flight demonstration activities that are planned which lead to the operational demonstration of the manned GEO mission capability. These activities are based on the assumption that the SR&T program described in subsection 8.4 has been implemented.

The flight demonstration activities include Shuttle assisted MOTV system/operational development, unmanned OTV flight and the initial manned OTV flight. These activities and their timing are shown in Fig. 8-13. All activities are part of the MOTV phase C/D program.

The initial development is a space demonstration of on-orbit assembly of the MOTV. A representative Drop Tank is assembled with a representative Propulsion Module which is held in position by the Orbiter. The representative aspect of the demonstration models covers accurate hard point dimensioning and approximate correlation of weight, volume and center-of-gravity conditions. This development activity demonstrates the ability of the Orbiter and its manipulator system to handle and position MOTV modules and the capability of man in EVA to complete the assembly of these modules.

The next development activity is a flight demonstration of the Crew Module manipulator/grapppler system. This system consists of the prototype manipulator developed by the SR&T program and a development grapppler produced by the CM phase C/D. A satellite mock-up with replaceable modules and associated manipulator/grapppler displays and controls are also provided. These test articles will verify the capability of the manipulator/grapppler design and man operating IVA to perform manned GEO tasks such as satellite retrieval, module removal and module replacement.

REQUIREMENTS: DEVELOP GEO ENVIRONMENTAL DESIGN GUIDELINES INCLUDING SOLAR FLARE PREDICTABILITY, WARNING SYSTEM CONCEPT DEFINITION AND ALLOWABLE DOSE LEVELS/SHIELDING EFFECTIVENESS.

APPROACH: (a) ANALYSIS

(1) PREDICTABILITY

ANALYZE HISTORY OF MAJOR PROTON EVENTS (18TH, 19TH AND 20TH CYCLE) AND OPTIMIZE PRESENT SHORT/LONG TERM TECHNIQUES/PREDICTION AND MODELS FOR ANOMALOUSLY LARGE PROTON EVENTS. PREDICTION TECHNIQUES/MODELS WILL ADDRESS TIME OF OCCURRENCE, LOCATION, ENERGY SPECTRUM, TIME OF MAXIMUM FLUENCE, DECAY TIME (I.E., DURATION) & ASSOCIATED GEOPHYSICAL EFFECTS. PREDICTION GOAL IS 30 DAYS WARNING WITH 99% CONFIDENCE LEVEL. IF PREDICTION GOAL CAN'T BE ACHIEVED BY LATE EIGHTIES, PREDICTABILITY APPROACH WILL BE A TWO-STEP PROCESS. FIRST, A DEFINITION OF THE WARNING CAPABILITY THAT IS POSSIBLE BY THE LATE EIGHTIES AND SECOND, A DETERMINATION OF FAR TERM CAPABILITY (1990'S).

(2) LEVELS/SHIELDING

REVIEW THE STANDARDS ESTABLISHED FOR UNIT REFERENCE RISK CONDITIONS & DETERMINE IF HIGHER DOSE LEVELS ARE ACCEPTABLE CONSIDERING O-LET RELATIONSHIPS, RADIATION/OTHER STRESS INTERACTION & HZE PARTICLE EFFECTS. ESTABLISH DESIGN GUIDELINES FOR MULTI-LAYERED SHIELDS. IMPROVE SPECIFICITY OF DOSE PROJECTIONS BY REFINING PROGRAM FOR CALCULATING DOSES THROUGH VARIOUS SHIELDING CONFIGURATIONS.

(b) SENSOR

CONSIDERING PRESENTLY AVAILABLE & PROJECTED SATELLITES AND GROUND FACILITIES FOR OBSERVING, TRANSMITTING & PROCESSING OF SOLAR FLARE/RADIATION DATA, DEVELOPE AN ADVANCED WARNING SYSTEM CONCEPT TO ALERT MOTV CREWS AT GEO OF IMPENDING LARGE PROTON EVENTS. CONCEPT INCLUDES CONSIDERATION OF SENSORS FOR ON BOARD CM INSTALLATION TO PROVIDE LOCAL REAL-TIME ALERT TO MOTV CREW

1980	1981	1982	1983
1 2 3 4	1 2 3 4	1 2 3 4	1 2 3 4

SCHEDULE:

ANALYSIS

SENSOR

↑ C/D CM PROPOSAL

FUNDING:

\$200K

\$400K

\$600K

\$800K

TOTAL = \$1.8 M

1776-J18W

Fig. 8-6 Supporting Research & Technology, Solar Flare Prediction

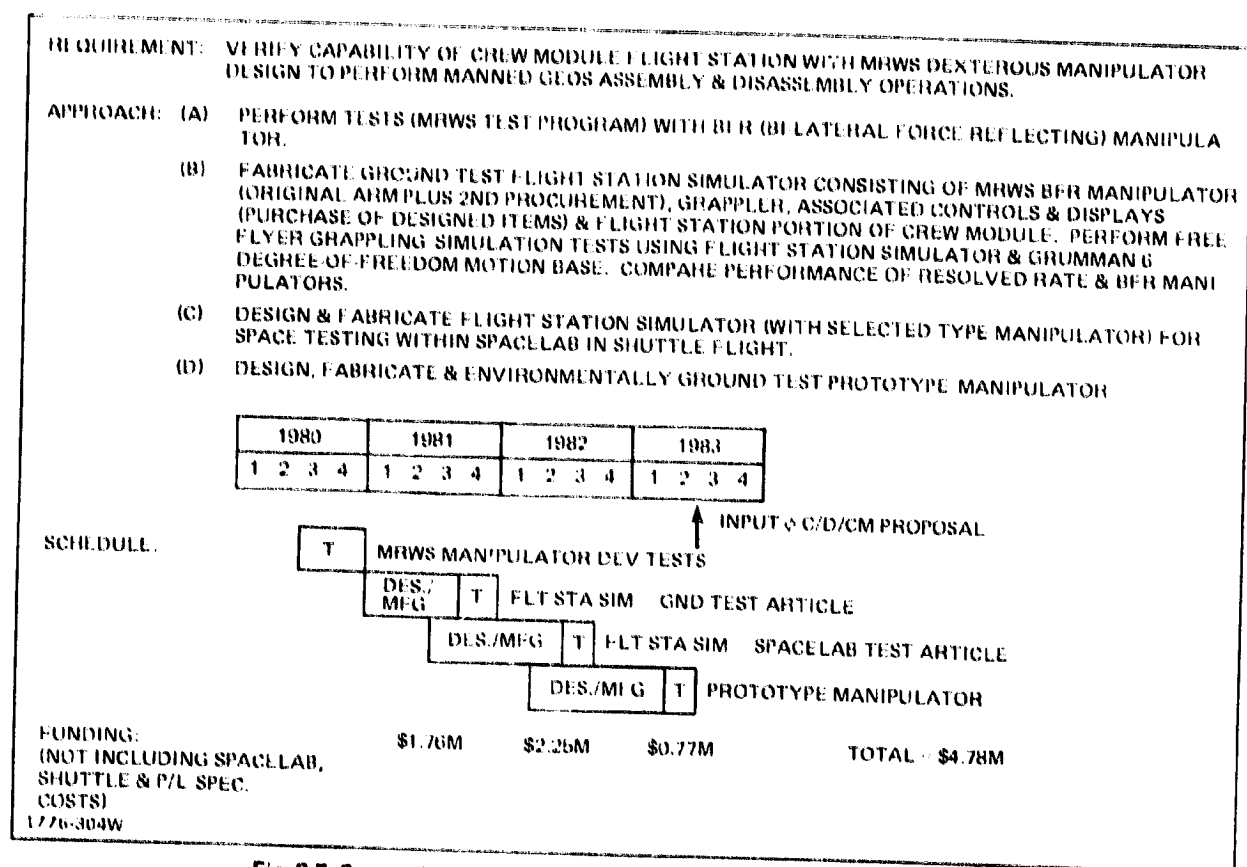


Fig. 8-7 Supporting Research & Technology, CM Flight Station Simulation

REQUIREMENT: DEMONSTRATE FEASIBILITY OF ON-ORBIT ASSEMBLY OF MOTV MODULES.

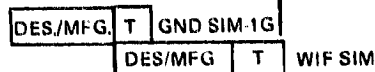
APPROACH: (A) DESIGN, FABRICATE & ASSEMBLE PROPULSION MODULE SIMULATOR WITH ACCURATE SIMULATION OF PROPULSION MODULE CORE HARD POINTS & CRUDE STRUCTURE TO REPRESENT PM PHYSICAL DIMENSIONS. FABRICATE LIGHTWEIGHT DROP TANK MODEL WITH ACCURATE ATTACHMENT POINT REPRESENTATIVE. PERFORM SIMULATED PM/DROP TANK ASSEMBLY OPERATION DEMONSTRATION USING JSC MANIPULATOR DEVELOPMENT FACILITY.

(B) DESIGN, FABRICATE & ASSEMBLE NEUTRALLY BUOYANT DROP TANK MODEL & STS/PROPULSION MODULE HOLDING FIXTURE/CRADLE FOR ON-ORBIT ASSEMBLY DEMONSTRATION OF PROPULSION MODULE MODEL (FROM ABOVE) AND DROP TANK NEUTRALLY BUOYANT MODEL IN JSC WATER IMMERSION FACILITY (WIF).

1980				1981				1982				1983			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4

↑ INPUT ϕ C/D PM PROPOSAL

SCHEDULE:



FUNDING:

(NOT INCLUDING
WIF COSTS)

\$250K \$950K \$650K TOTAL = \$1.85 M

1776-303W

Fig. 8-8 Support Research & Technology, On-Orbit Assembly Simulation

REQUIREMENT: DEMONSTRATE FEASIBILITY OF GEO SUIT COMPATIBLE WITH EVA ENVIRONMENT & WORK TASKS.

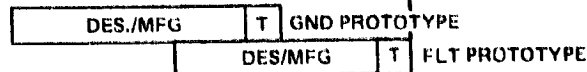
APPROACH: (A) DESIGN, FABRICATE & TEST GROUND PROTOTYPE THERMAL HAZARD RADIATION OVERGARMENT, HELMET & GLOVES COMPATIBLE WITH GEO ENVIRONMENT AND ADVANCED LEO SUIT; EVALUATE CAPABILITY OF SUIT TO PERFORM GEO WORK TASKS.

(B) REFINE DESIGN & FABRICATE PROTOTYPE GEO ENVIRONMENT HARDWARE FOR TESTING WITH ADVANCED LEO SUIT IN LEO VIA STS FLIGHT. EVALUATE CAPABILITY OF SUIT TO PERFORM GEO TYPE WORK TASKS & MEASURE METABOLIC OUTPUT.

1980				1981				1982				1983			
1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4

↑ INPUT ϕ C/D CM PROPOSAL

SCHEDULE:



FUNDING:
(NOT INCLUDING
STS COST)

100K 550K 650K 200K TOTAL \$1.5M

1776-305W

Fig. 8-9 Support Research & Technology, GEO EVA Suit Development

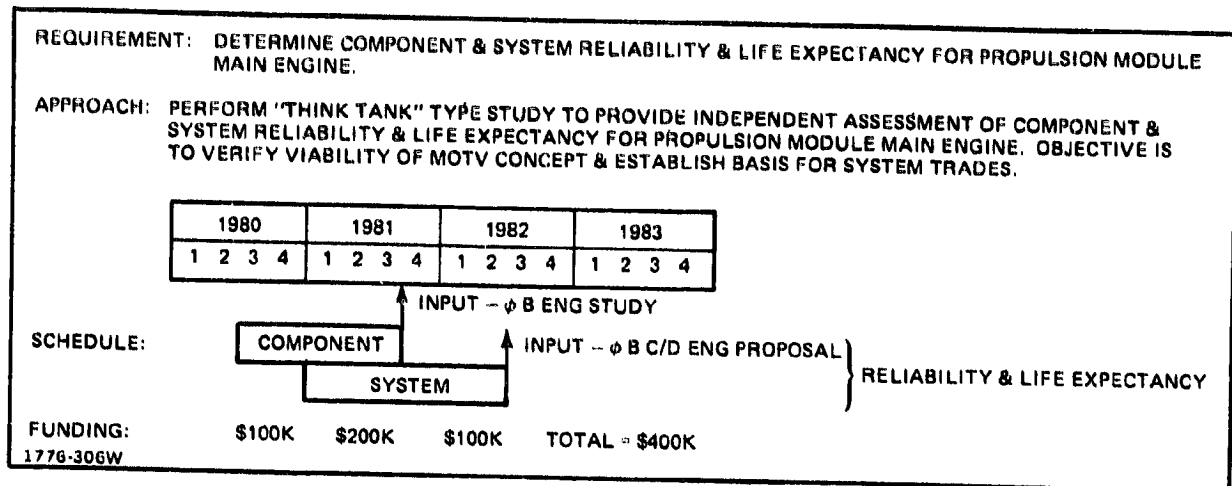


Fig. 8-10 Supporting Research & Technology, Main Engine Life & Reliability

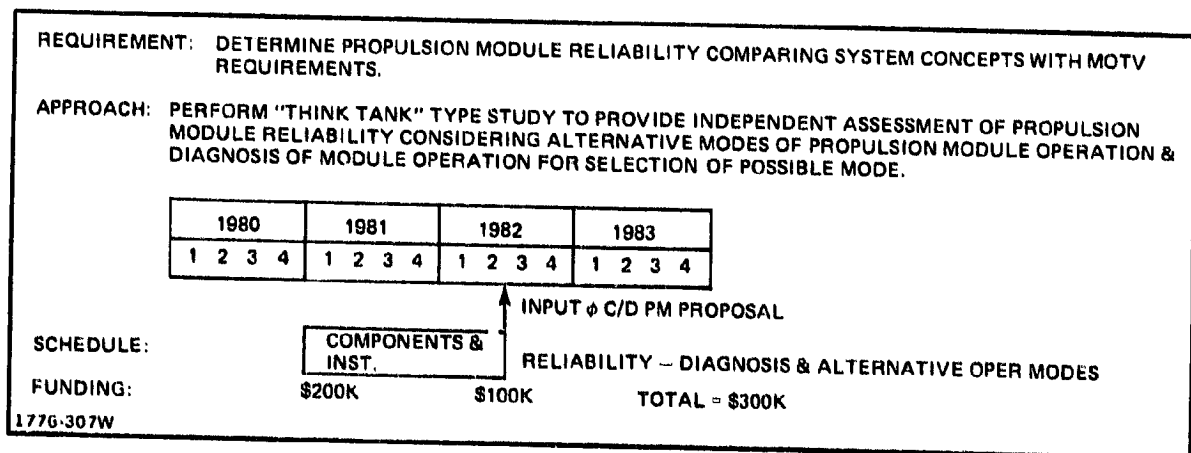


Fig. 8-11 Supporting Research & Technology, Propulsion Module Reliability

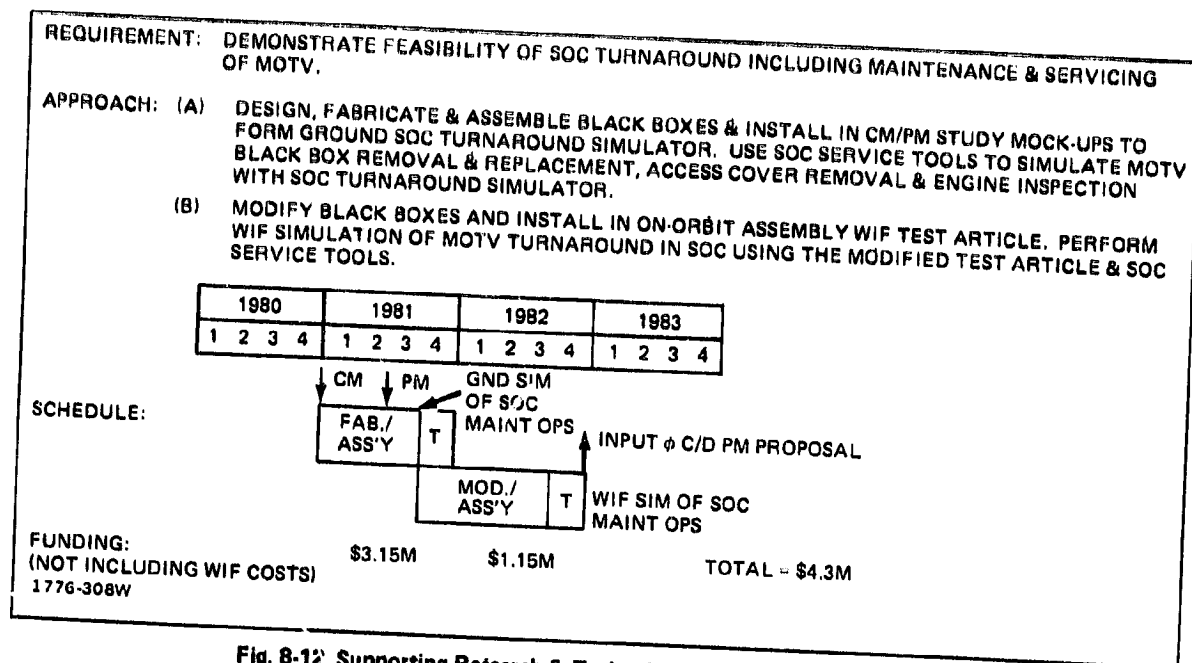


Fig. 8-12 Supporting Research & Technology, SOC Turnaround Simulation

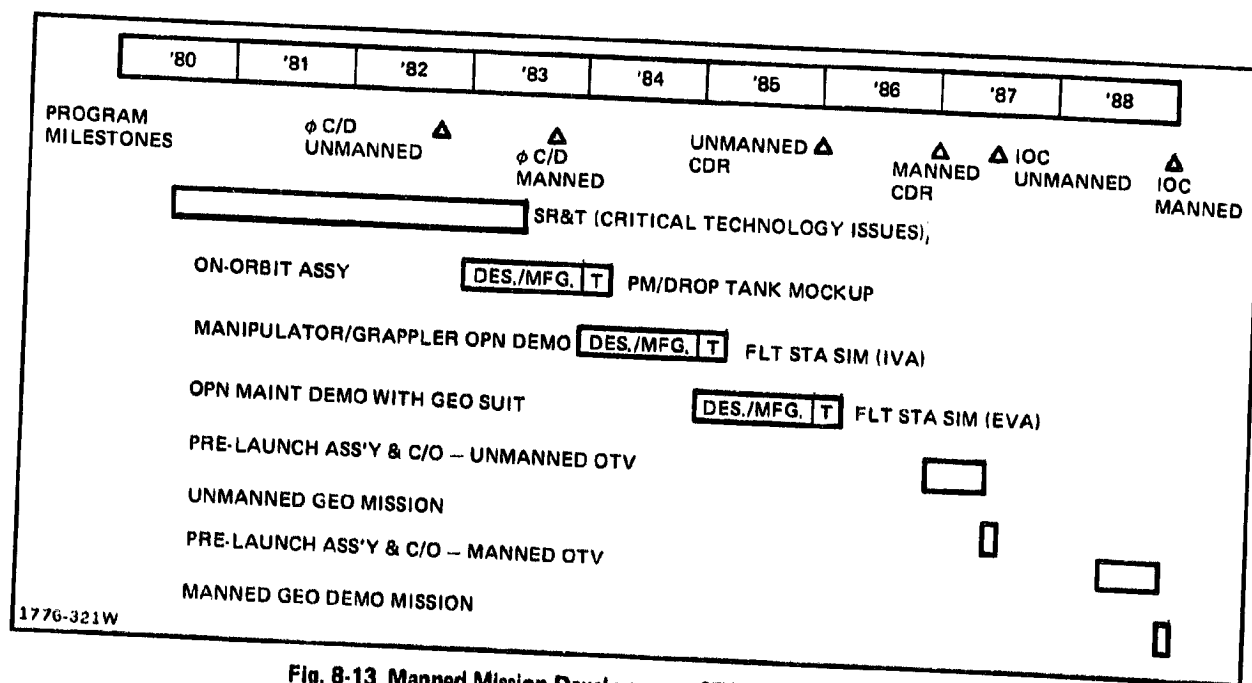


Fig. 8-13 Manned Mission Development, STS Flight Requirements

The test article utilized in the above demonstration is modified to increase the complexity of the maintenance and servicing operations. The increased complexity requires man in EVA to assist the IVA manipulator/grapppler function. This capability is demonstrated by the modified test article with man operating EVA in the prototype GEO suit developed and tested in the SR&T program.

The completion of the Shuttle assisted development tests set the stage for the OTV flights. The first flight is an unmanned OTV flight. The unmanned flight not only demonstrates the operational readiness of the OTV including PM core/engine and Drop Tanks but qualifies the PM for manned OTV flights. The unmanned OTV flight is planned to GEO since the probability of OTV recovery in the event of failure for a flight to higher earth orbit is considered extremely low.

The last manned mission development is the first manned OTV flight. This flight preceded by a ground man-rating of the CM as well as the development activities described above includes the completion of a representative mission at GEO. The successful culmination of this flight is the operational demonstration of manned GEO mission capability.

9 - MOTV INTEGRATED SCHEDULE & COST

The integrated or master schedule for the MOTV program is given in Fig. 8-4, previously utilized in the MOTV module discussion. The master schedule has been time phased for the orderly development of the MOTV capability. The significant features of this schedule include:

- early system and module definition studies time phased for appropriate interaction between studies
- addressing and resolution of major cost impact issues in the studies
- SR&T activity to resolve "show-stopping" critical technology issues prior to major program decisions
- long-range requirements incorporated into design requirements, i.e., man-rating requirements included in the initial design of unmanned modules.
- concentration in early years activity on critical issues to limit funding requirements

The cost of the MOTV program is presented in Fig. 9-1. The costs have been developed in accordance with the assumptions defined in Section 6. The program costs are broken-out by major program function or hardware element and program phase as well as summarized into sub-total and total requirements. Key costing assumptions such as year dollars, weight contingency and production quantity are also noted in Fig. 9-1.

The funding schedule associated with the Fig. 9-1 program costs and the Fig. 8-4 master schedule is shown in Fig. 9-2. These funding requirements include the study/ SR&T and phase C/D costs. The study/SR&T funding requirements for each of these categories is plotted to an enlarged scale in Fig. 9-3. As noted above, the MOTV program plan is keyed to the lowest early year funding requirements consistent with the resolution of critical issues in support of major program decisions.

	DDT&E	PRODUCTION (2 VEHICLES)	TOTAL
PROJECT MANAGEMENT	51	16	67
SE & I	71		71
SPACE VEHICLE	1028	196	1224
CREW CAPSULE	602	115	617
PROPULSION CORE	391	69	460
DROP TANKS	135	12	147
GROUND SUPPORT SYS	166	—	166
OPERATIONS	13	—	13
FLT SUPPORT EQUIP.	47	2	49
SPACE TRANSPORT	71	—	71
INST ASSY CHECKOUT	—	40	40
SYS TEST & EVAL	22	—	22
1776-322W	1469	254	1723

Fig. 9-1 MOTV Development/Production Cost Summary — Mission S1
(25% Weight Contingency Reflected — Constant 1979 \$ M)

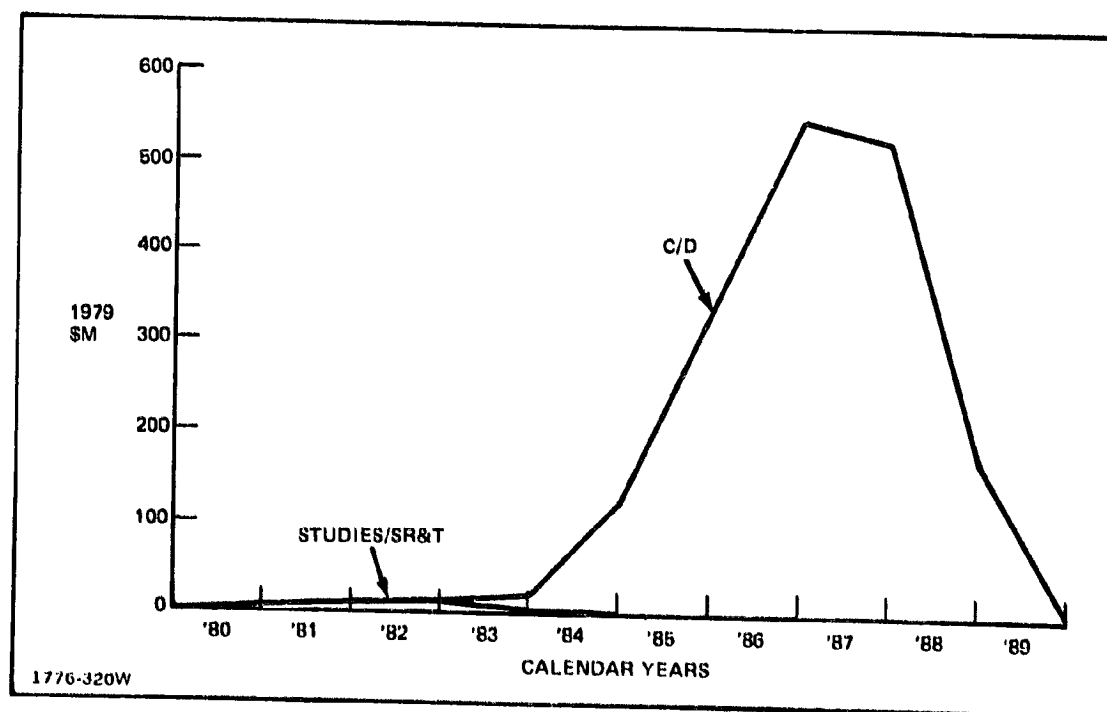


Fig. 9-2 Annual MOTV Program Funding Requirements

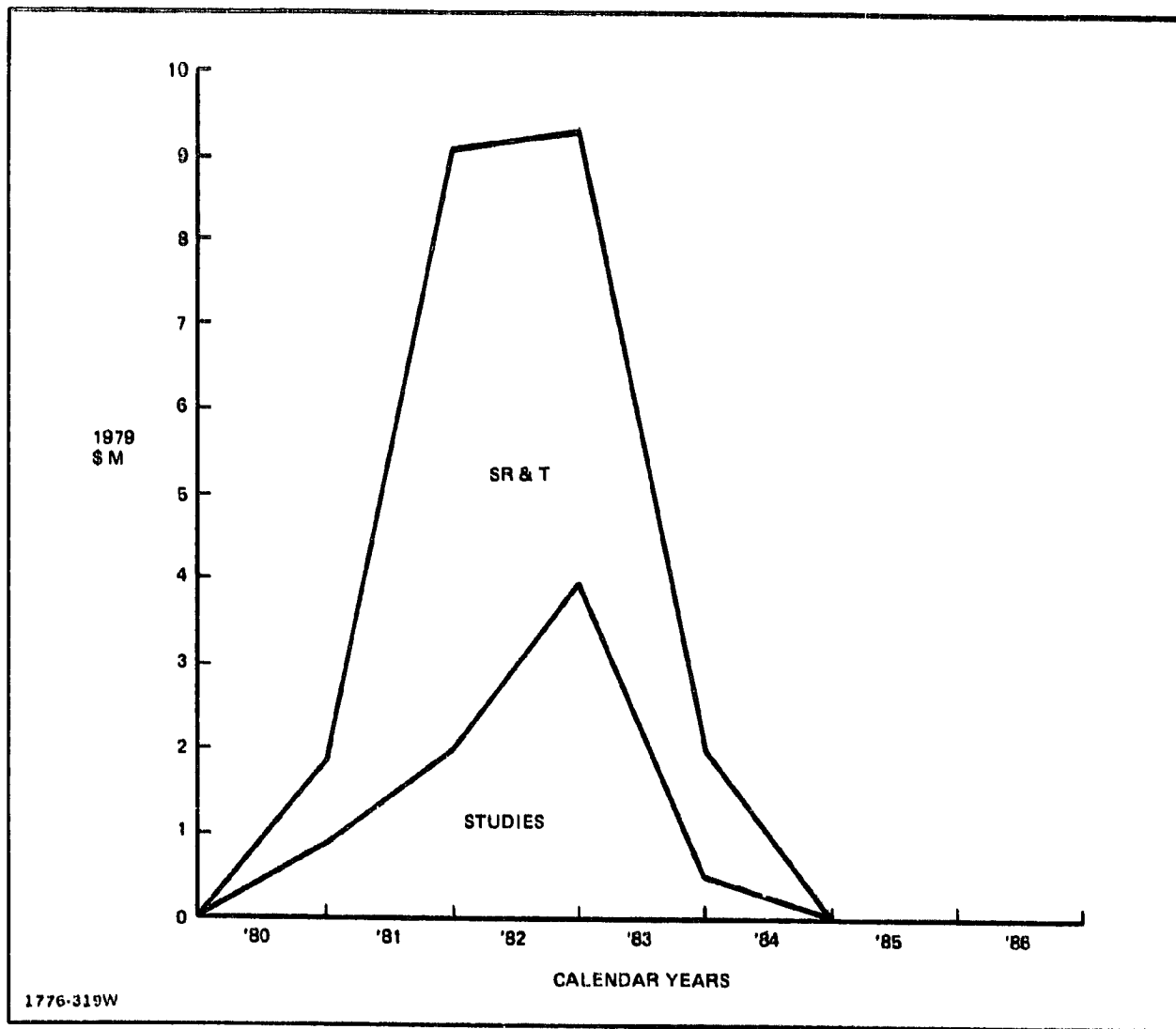


Fig. 9-3 Annual MOTV Studies & SR&T Funding Requirements